Chapter 5 Chilean needle grass (*Nassella neesiana*) Regional Best Practice Management

5.1 Abstract

Chilean needle grass (*Nassella neesiana* (Trin. & Rupr.) Barkworth, CNG) has perennial characteristics that allow it to persist in pasture and out compete the more desirable species. Once reproductive, CNG produces numerous unpalatable flower stalks and little leaf material, reducing stock rate and grazing utilisation. This chapter describes an experiment that commenced in 2003, comparing set stocking to strategic grazing of a CNG dominated pasture with treatments of chemical control, fertility and pasture rehabilitation to attempt to reduce the dominance of CNG in different climatic regions.

Set stock grazing led to a shift in pasture composition to annual species with broadleaf weeds. Flupropanate application (1.5l/ha 745g a.i./l) decreased the basal cover of CNG at all sites although the residual effect varied between the sites. Off target damage by flupropanate was normally restricted to the season post spraying although grazing management effected the recovery of desirable perennial species. Set stock grazing of flupropanate plots, as opposed to strategic or lockup plots, shifted the pasture composition to annual grasses and broadleaf weeds with large areas of bare ground. In flupropanate plots that had large areas of bare ground (typically set stock plots), the residual effect of the herbicide was less apparent as CNG basal cover increased within two seasons of treatment application.

Glyphosate was able to kill mature CNG plants and enable resowing of perennial pastures, where seasonal conditions were favourable for pasture establishment. CNG was able to re-invade resown plots within the experimental period due to low pasture competition, and no residual herbicide activity.

The use of glyphosate at 'selective rates' led to increased bare ground and reduced pasture competition leading to more broadleaf weeds at Glen Innes.

Spraytopping at Glen Innes had minimal effect on desirable perennial species whilst reducing CNG basal cover, CNG standing panicle seed, and CNG panicle seed viability.

Timing of strategic grazing during the reproductive period was critical to reducing panicle seed maturation. Sheep stocked equivalent to 300DSE/ha tended not to graze CNG stems once the panicle seed had emerged.

5.2 Introduction

A general theory in agricultural extension literature is that good grazing management can increase competition of beneficial pasture species resulting in a long term decline in undesirable weed species (DNRE 2002; DPI 2000; Hill 1997; NSW-Agriculture 1998; Taylor and Sindel 2000; Warn 1995). It has also been shown that in some circumstances increased soil fertility can provide a competitive advantage to beneficial grass species over undesirable weed species (DNRE 2002; DPI 2000; Taylor and Sindel 2000). Similarly strategic use of chemical control can be used to reduce weed dominance (Bedggood 2000; Bourdot 1988; Campbell 2002; Duncan 1993; Pritchard 2002; 2003; 2004; Storrie and Gardener 1998) while pasture rehabilitation is a recognised tool for renovating pastures and decreasing weed dominance (Dowling *et al.* 2000; Jackson and Caldwell 1992; Taylor and Sindel 2000).

Given that Chilean needle grass (*Nassella neesiana* (Trin. & Rupr.) Barkworth, CNG) growth appears to be sensitive to rainfall, and this sensitivity could be an interaction of temperature and rainfall (Gardener 1998), it is highly likely that the variation in plant vigour due to climate will strongly affect the success of management treatments. These experiments are aimed at comparing set stocking with strategic grazing of a CNG dominated pasture combined with treatments of chemical control, fertility and pasture rehabilitation to reduce the dominance of CNG in different climatic regions.

5.2.1 Grazing management – grazing method and pasture species

In terms of animal grazing preference, desirable pasture species are generally disadvantaged as they are more palatable and are selected in preference to undesirable plants (Friend and Kemp 2000). Selective defoliation of palatable species allows unpalatable species to grow unchecked and realise a competitive advantage (Moretto and Distel 1999). Moretto and Distel (1999) also found that in the presence of defoliated palatable plants, unpalatable plants had a larger basal area, end of season aerial biomass, seed production, total green blade length per tiller and tiller dry mass. They suggest that selectivity can be reduced by high intensity low frequency grazing events. This suggestion is assuming that the palatable species are at least as tolerant to grazing as are the unpalatable species.

5.2.2 Grazing management - stock rate

Stock rate is the dominant management factor in determining the efficiency of pasture utilisation by sheep and cattle (McMeekan and Walshe 1963). Grazing method is less important than the stock rate although there are significant interactions between stock rate and grazing method (McMeekan and Walshe 1963).

If the stock rate is too high, pasture production will be reduced and there is the risk of destroying the pasture community causing less palatable species to become dominant (McGregor 2002). Apart from the nutritional stress imposed on the stock, there are also concerns about soil conservation and bare soil providing opportunity for weed invasion.

Appropriate stock rates can be calculated based on the animals' Dry Sheep Equivalent (DSE) requirement. One DSE unit is the estimated energy requirement to maintain body weight of a two year old wether/non breeding merino sheep weighing 45kg (McGregor 2002). The DSE requirements of an animal depend upon the average body weight, rate of growth, pregnancy status, physical activity and cold stress.

5.2.3 Pasture renovation considerations – pasture species

The pasture species that are sown to compete against weeds should be suited to the climate, rainfall, soil type, and grazing regime. The seed intended to be used should be clean, and preferably a larger or more competitive plant than the weed (Bedggood 2000). It is also wise to have a range of pasture types to make management flexible (NSW-Agriculture 1998).

The ability of a pasture to compete against weeds is affected by the pasture species present, leaf area of the pasture, soil type, soil moisture, temperature, fertiliser history and grazing history (NSW-Agriculture 1998). The growth of pasture grasses is based on the production of tillers that are continually produced and die due to shading or moisture stress. Thus, by using animals to keep pastures 'short' (i.e. 5-15 cm) light is able to reach most of the plant material and stimulate growth (NSW-Agriculture 1998). Overgrazing can lead to severe defoliation that will weaken the pasture plants resulting in a change in the vegetative composition towards annual plants that are sensitive to environmental change. If an annual pasture is subject to a period of low rainfall, vegetative cover becomes sparse leading to bare soil and risk of soil erosion (Friend and Kemp 2000; Van de Koppel *et al.* 1997).

Friend and Kemp (2000), believe that a paddock is overgrazed if it has less than 500 kgDM/ha or less than 20% perennial grasses. Overgrazing occurs when the grazing pressure is too high and the meristematic zone (region of closely dividing cells), which is close to the soil surface, is grazed off inhibiting plant growth.

5.2.4 Chemical control of Chilean needle grass – mature plants

Glyphosate is a non-selective herbicide that is able to kill standing CNG plants and minimise seed production (Bourdot and Hurrell 1987; Campbell 1995a; b; Lowien 2002; Nufarm 2005; Pritchard 2003; 2004; Slay 2001; 2002a; b; Stapleton 1995; Storrie and Gardener 1998; Taylor and Sindel 2000). Glyphosate applied at 540g a.i./ha during autumn can achieve a 90% kill of CNG, although it is less effective when sprayed in spring and summer (Bourdot and Hurrell 1987; Storrie and Gardener 1998).

The application of glyphosate (33% glyphosate in water) through a herbicide wick wiper during spring to one or both sides of CNG killed 44% of CNG after 2 months (Bourdot and Hurrell 1987). The remaining 56% had surviving tillers that were most likely from seeds in dead tillers (up to 10 seeds) or from fallen seed.

As a selective herbicide, flupropanate can be used to limit damage to off target pasture species such as Phalaris (*Phalaris aquatica*) and Kangaroo grass (*Themeda triandra*). Literature related to the use of flupropanate in different soil types and management contexts is not readily available and constitutes the basis for experimentation in this thesis. When sprayed in spring or autumn it can give 75% control of CNG when sprayed at 1117.51 a.i./ha or 100% control sprayed in spring at 22351 a.i./ha (Gaur *et al.* 2005). Flupropanate has also been shown to give high levels of CNG control in other trials (Duncan 1993; Storrie and Gardener 1998; Williams 2005). Flupropanate based herbicides have also been useful in controlling seedlings of serrated tussock in young improved pastures (Campbell 1997a).

The use of 2,2-DPA has successfully suppressed established CNG selectively at rates of 2.0 kg a.i./ha in New Zealand when sprayed during May, December and February but not in August (Bourdot and Hurrell 1987). Off target species included hair grass (*Vulpia bromoides*), barley grass, wallaby grass (*Danthonia spp.*), ryegrass (*Lolium perenne*), plantain (*Plantago lanceolata*).

5.2.5 Chemical control of Chilean needle grass – seedlings

Trials in Hawke's Bay, New Zealand, comparing 25 different herbicides have had little success at eradicating CNG (Slay 2002b). Repetitive spraying for regrowth and seedlings, with grass selective or non selective herbicides, in pasture encouraged CNG re-establishment and exacerbated its spread as desirable pasture species were removed.

A long term approach combining herbicides and lucerne as a competitive pasture was trialed by Bourdot and Hurrell (1987). In this experiment they were able to decrease the mass of CNG growing in the lucerne by 99%. To achieve this result they sprayed glyphosate (1.08 kg a.i./ha) in autumn to kill all mature CNG plants. After a winter fallow, 10 kg/ha of rhizobia inoculated WL318 lucerne was sown to 13 mm depth. CNG seedlings were controlled either pre-sowing or at early post emergence. The pre-sowing treatment was applied five hours prior to sowing, EPTC (5.8 kg a.i./ha) or trifluralin (1.0 kg a.i./ha) was incorporated 70 mm into the soil. Pre sowing seedling control was effective with EPTC reducing seedling density by 90% and raising lucerne yield by 85%, thus indicating a strong competitive ability of CNG to utilise soil water. The use of trifluralin reduced CNG dry matter by 97% when compared to the control plots. Trifluralin has also been effective in reducing the soil seed bank of CNG by up to 96% in a conventional cultivation system or 93% in a minimum tillage system (Gardener 2001).

Bourdot and Hurrell (1987) found that CNG seedling control at early post emergence (lucerne at one to three trifoliate leaf stage; CNG beginning to tiller) using fluazifop butyl (0.75 kg a.i./ha) or alloxydim-sodium (1.5 kg a.i./ha) was not as effective as EPTC during the second growing season. When used in direct drilled soybeans, fluazifop-P (rate unknown) reduced the soil seedbank by 71.9% (Gardener 2001). Carbetamide application, at early post emergence, was considered to be ineffective against CNG seedlings even at 4.2 kg a.i./ha (Bourdot and Hurrell 1987).

In the following winter Bourdot and Hurrell (1987) found that the application of triazine herbicides mixed with paraquat gave >99% reduction of CNG where used on plots pre treated with EPTC, trifluralin, fluazifop-butyl or alloxydim-sodium the season before. The triazines used, respectively mixed with paraquat, were atrazine (1.0kg a.i./ha + 0.6kg a.i./ha), simazine (1.2 kg a.i./ha + 0.4kg a.i./ha) or metribuzin (0.35 kg a.i./ha + 0.4 kg a.i./ha). Metribuzin was tolerated by the lucerne better than the other triazines. The use of propyzamide (0.5 kg a.i./ha) or 2,2-DPA (5.9 kg a.i./ha) on pre plant or early post emergence plots (except EPTC) were ineffective in controlling CNG seedlings.

From these trials Bourdot and Hurrell (1987) recommended the safe and effective control of CNG seedlings using pre-sowing EPTC or early post emergence fluazifop-butyl followed by metribuzin and paraquat in the spring.

5.2.6 Experimental aims

The aims of these experiments were to identify best practice management treatments for CNG, and compare the effectiveness of these treatments across 4 different regions that have CNG infestations. The treatments included cultural techniques such as pasture resowing (with fertiliser), as well as chemical control strategies and grazing management using sheep.

5.3 Materials and method

5.3.1 Locations

Four field trials were established to assess CNG management treatments in different geographical regions. The sites were positioned on sheep grazing properties that had infestations of CNG within the existing pasture sward. These trial sites represented the Australian distribution of CNG ranging from Victoria (Greenvale 'The Elms' 38°04' S, 141°40' E; Toolleen 36° 40' S, 144°40' E) through to New South Wales (Goulburn 34°47' S, 149°44' E; Glen Innes 30°44' S, 151°40' E)(Figure 5.1). Since this project commenced, CNG has also been found in Tasmania, South Australia and Queensland (Iaconis 2006).

Bureau of Meteorology data from weather stations in proximity to the trial sites were used for rainfall and temperature monitoring. Bureau of Meteorology weather stations at the local airports were used for trial sites at Greenvale (Melbourne Airport), Goulburn and Toolleen (Bendigo Airport and Redesdale town) whereas weather stations located in town were used for Glen Innes.

The trial sites, and the management strategies undertaken at each site, can be categorised by the predominant rainfall patterns for their region. The 3 southern sites (Greenvale, Toolleen and Goulburn) are in the winter rainfall zone, where the majority of pasture growth occurs during winter and spring. During the experimental period these sites received lower than expected and unseasonal rainfall that impacted on pasture growth. Glen Innes is in the summer rainfall region, allowing the production of both winter and summer crops. Total annual rainfall is given in Figure 5.2, total monthly rainfall for the sites can be seen in Figure 5.3, Figure 5.4 and Figure 5.5, and mean monthly temperatures seen in Figure 5.6, Figure 5.7 and Figure 5.8.

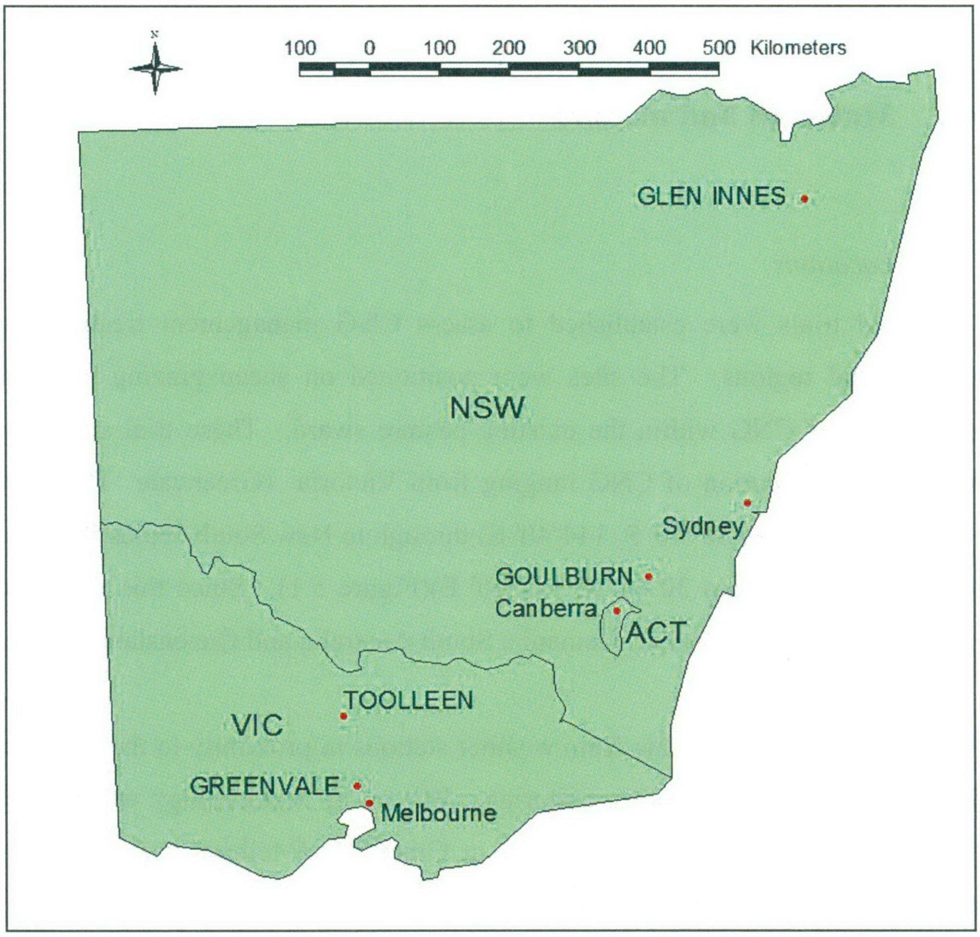

Figure 5.1 Map of trial site locations in Victoria and New South Wales, Australia

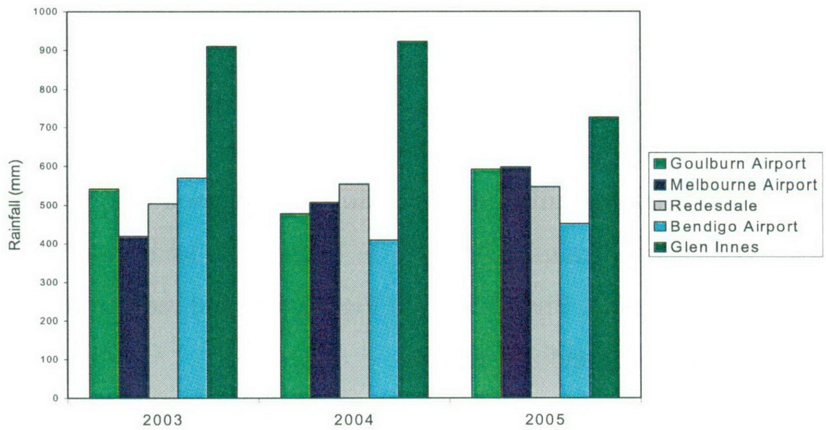

Figure 5.2 Total annual rainfall at the trial sites.

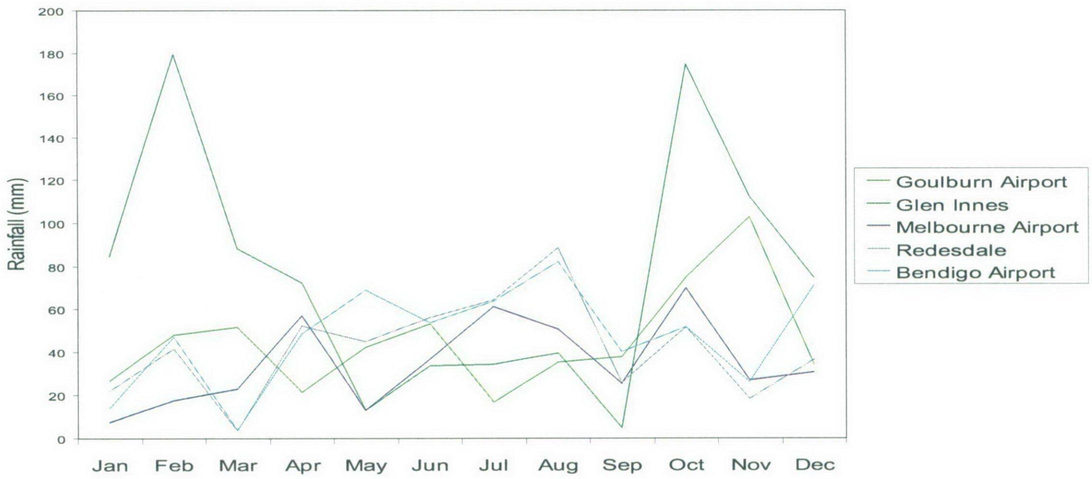

Figure 5.3 Total monthly rainfall at trial sites for 2003 (mm).

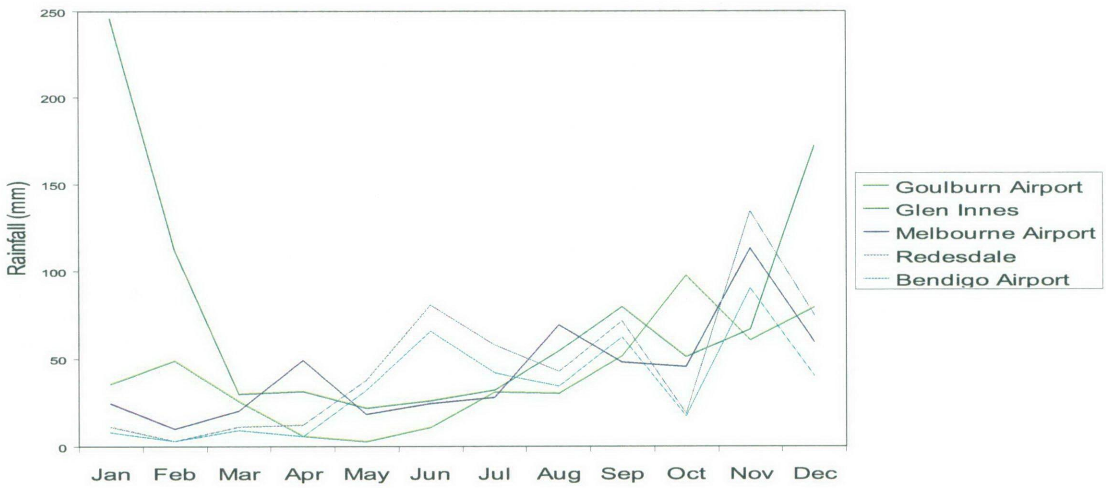

Figure 5.4 Total monthly rainfall at trial sites for 2004 (mm).

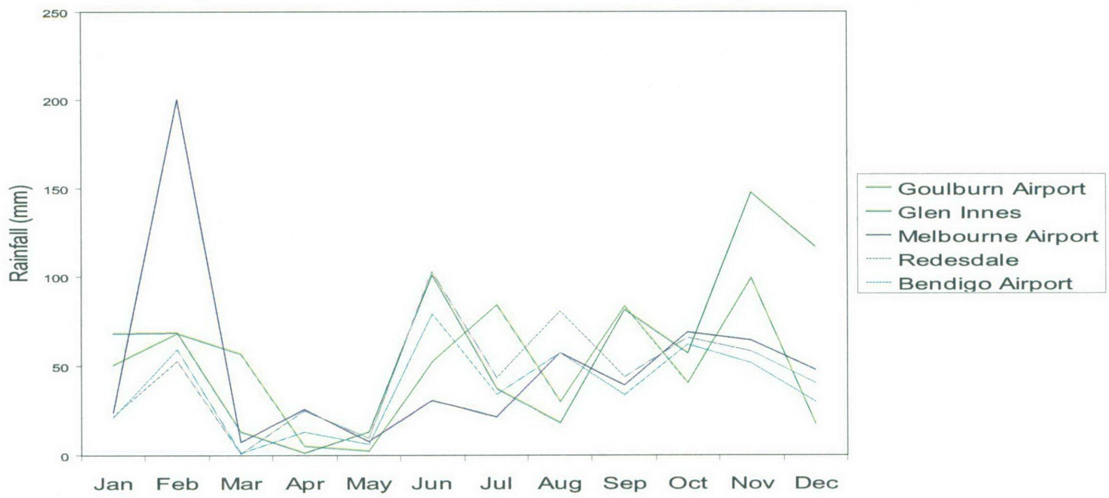

Figure 5.5 Total monthly rainfall at trial sites for 2005 (mm).

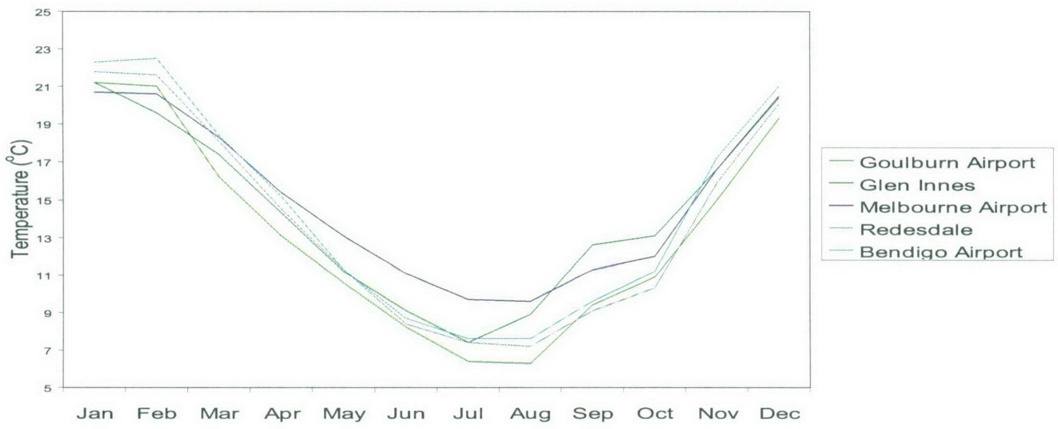

Figure 5.6 Mean monthly temperature at trial sites for 2003.

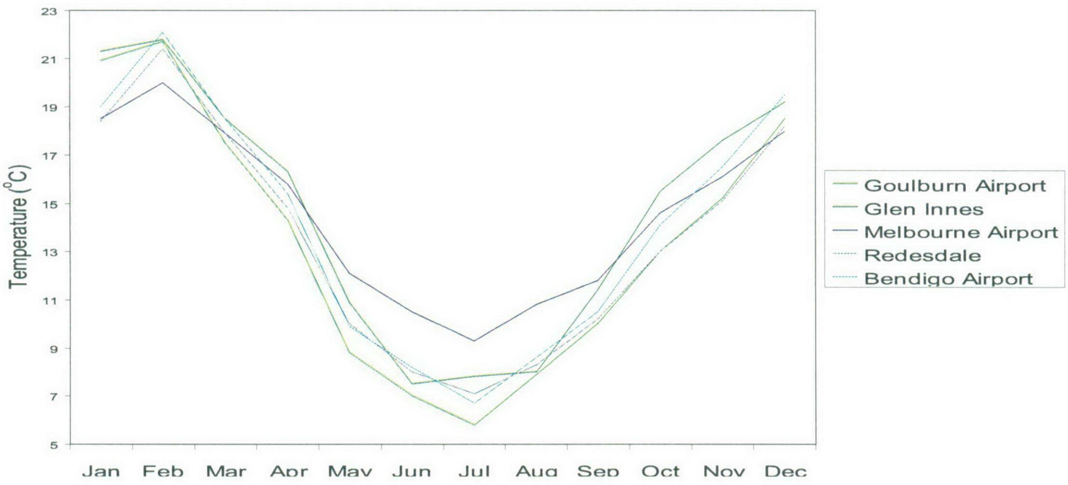

Figure 5.7 Mean monthly temperature at trial sites for 2004.

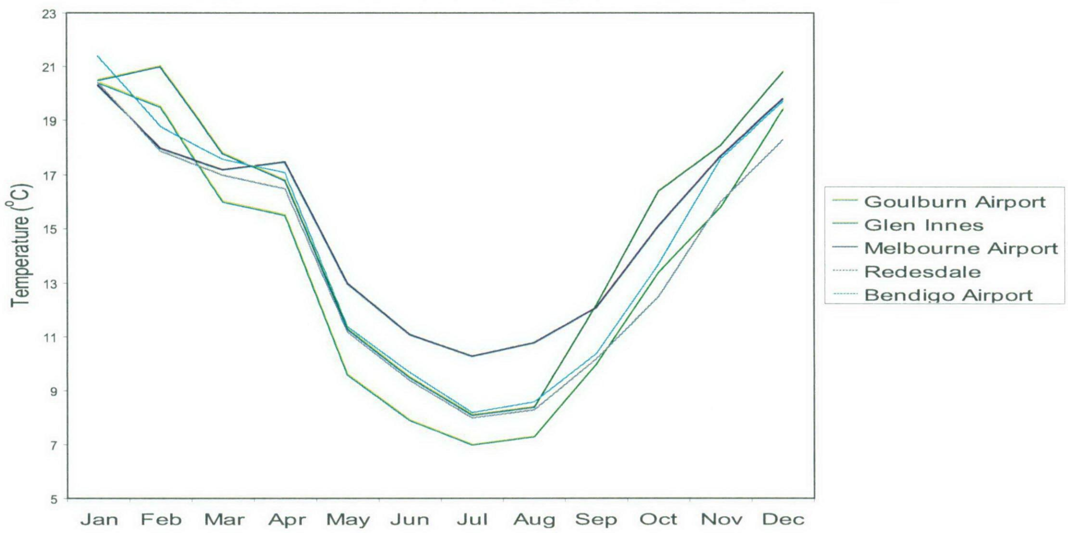

Figure 5.8 Mean monthly temperature at trial sites for 2005.

5.3.2 Design and treatments

Each trial was constructed in a randomised block design with three blocks (replicates) per site, comprising of fenced off plots (each plot 100 m^2; except lockup and set stock plots at Greenvale which were 25 m^2). Sites at Greenvale, and Goulburn (Figure 5.9) had 10 treatments (Table 5.1) whilst Toolleen (Figure 5.9) had 8 treatments (Table 5.2) and Glen Innes had 12 treatments (Table 5.3, Figure 5.9). Treatments were chosen to suit the district practice and seasonal conditions. Fences of all plots were made of sheep proof mesh (Ringlock), with water troughs placed in the experimental paddocks and plots during grazing periods (Figure 5.10).

5.3.3 Grazing regime

'Set stock' plots were open at one end such that they received the same grazing pressure as the experimental paddock within which the trial was located (Greenvale, Goulburn, Glen Innes and Toolleen approx. 12 DSE/ha). This form of continuous grazing was also flexible enough to allow for destocking of the experimental paddock during periods of severe flowering. At Goulburn, the paddock did not have to be destocked during flowering since the flower stalks were mechanically topped annually in spring. 'Strategic' grazing plots were grazed by 3 or more sheep for short periods on an as needed basis to reduce the production of CNG flower heads and limit grazing selectivity. The sheep used for the strategic grazing plots were yarded from the experimental paddock mob and placed in to the plots at 2500 – 3000 kg DM/ha and were removed when dry matter yields had been reduced to 800 – 1000 kg/ha. Strategically grazed plots were typically grazed 5 times throughout the year at a minimum stocking rate of 300 DSE/ha equivalent. 'Lock up' plots are ungrazed and totally excluded grazing stock (Figure 5.11).

Sheep used in the experiment were generally merino and merino cross ewes and lambs, with few Suffolk cross ewes at Greenvale. Sheep age ranged from lambs to 7 year old stock, with all sheep accustomed to the district in which they were grazing prior to the experiment.

5.3.4 Resowing procedure – pasture at all sites

Soil tests were taken to determine the correct fertiliser and pasture seed mix to sow at each site (Table 5.5). Only treatments that were to be sown down to pasture seed were fertilised, except at Glen Innes where all treatments received fertiliser and white clover (250kg/ha single super and 2kg/ha Huia white clover (*Trifolium repens*), 12th December 2003). Pasture seed was sown aerially at Goulburn during 2003, and direct drilled at Greenvale, Toolleen, Glen Innes and Goulburn (2004; Figure 5.12). Pasture varieties, cultivars and time of sowing were chosen to suit the district conditions. Due to seasonal conditions pastures failed to establish and were resown at all sites in the following season (Table 5.7). This second attempt at pasture resowing was more successful than the first, although seasonal conditions were not favourable at the time of sowing.

5.3.5 Resowing procedure – cropping at Glen Innes

Plots that included a 'cropping' treatment at Glen Innes were sown to pasture after a cropping phase. Cropping plots were sprayed with glyphosate 1125 g a.i./ha on the 11th September 2003, chisel ploughed on the 23rd October 2003 and cultivated on the 12th December 2003 with a cultivator. Cropping plots were sown to soybeans on the 17th December 2003 using the pre emergent herbicide trifluralin 960 g a.i./ha incorporated. Soybeans were sown at a rate of 70 kg/ha with 125 kg/ha of Single Super (8.8% phosphate, 11% sulfur) using a cone seeder. Soybeans were harvested on 12th May 2004 using a plot harvester, with an average yield of 2.0 t/ha. Oats were direct drilled into cropping plots at a rate of 87 kg/ha with Single Super Phosphate at a rate of 125 kg/ha on the 31st of May 2004. Cropping plots with oats were grazed from 21st to the 28th September 2004. A second cropping phase started with a cultivation on the 1st November 2004, pre-emergent herbicide trifluralin 960 g a.i./ha, and incorporated prior to being sown to soybeans on the 13th December a rate of 77 kg/ha with 125 kg/ha single super phosphate fertiliser. Soybeans were harvested on the 8th June 2005 with an average yield of 3.06 t/ha. Soybean stubble and trash were removed from the cropping plots on the 10th June 2005 in preparation for pasture resowing.

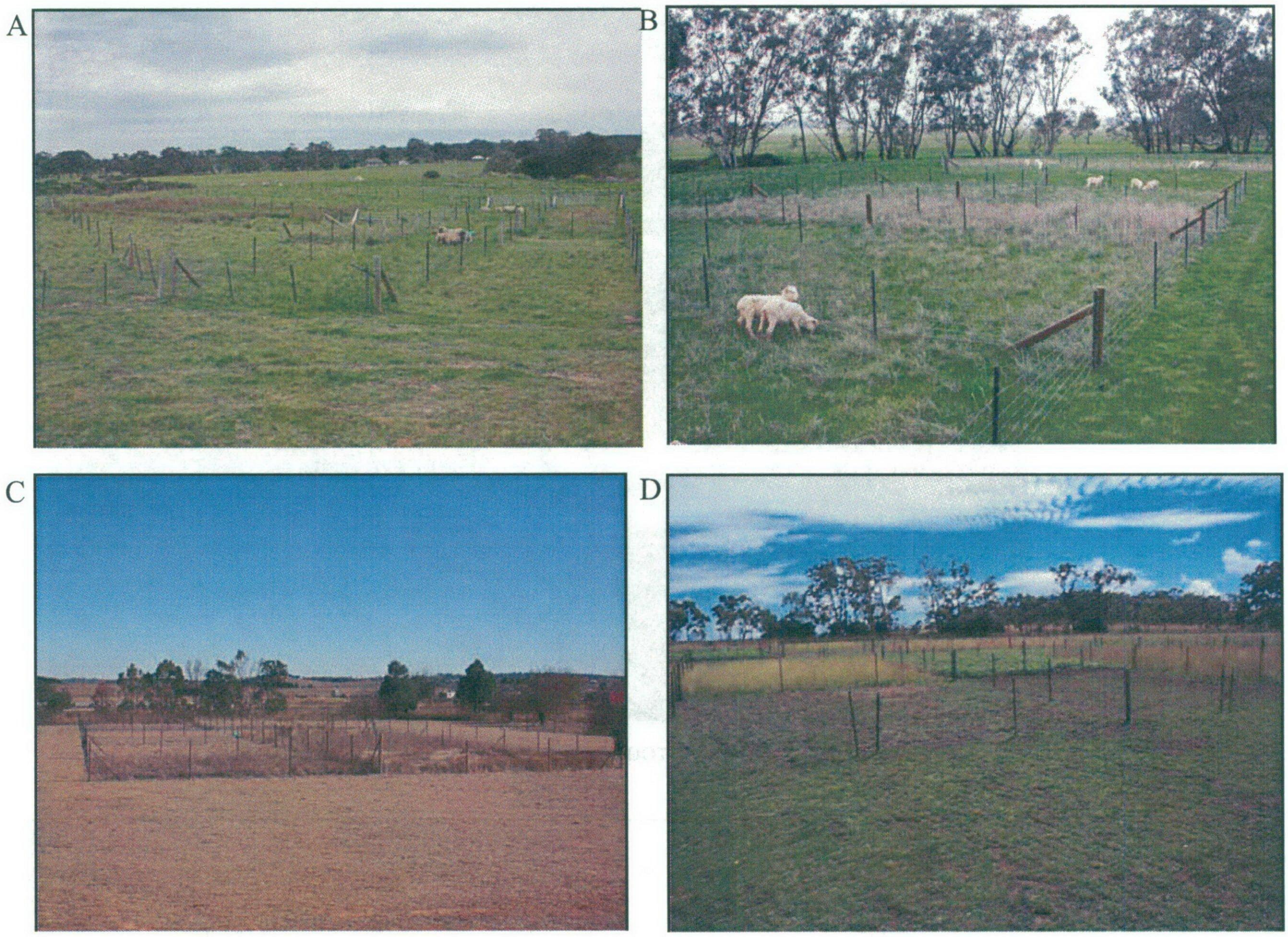

Figure 5.9 CNG Regional best practice management sites.- A) Greenvale, B) Toolleen, C) Goulburn, D) Glen Innes.

5.3.6 Spraying procedure

Plots at Greenvale and Toolleen were sprayed using a hand held boom sprayer (Azo-Dutch Sprayer). At Goulburn and Glen Innes, a boom sprayer mounted on a four wheel bike or a hand held sprayer was used to spray the plots.

5.3.7 Flupropanate application

Flupropanate plots were sprayed at a rate of 1.117kg a.i./ha on the 4th July 2003 at Toolleen and the 17th July at Greenvale (Lockup flupropanate treatments at both Toolleen and Greenvale were sprayed on the 21st October 2003). Flupropanate plots at Glen Innes were sprayed at a rate of 2.235 kg a.i./ha on the 30th September 2003. Goulburn flupropanate plots were sprayed at a rate of 1.490 kg a.i./ha on the 1st November 2002.

Figure 5.10 Water troughs as used at Greenvale trial site.

Figure 5.11 Strategic grazing at Greenvale trial site.

Table 5.1 Treatments applied at the Greenvale and Goulburn regional best practice sites.

Treatment	Grazing regime	Resow pasture	Herbicide
1	Set stock	No	None
2	Set stock	No	Flupropanate
3	Lock up	Yes	Glyphosate
4	Lock up	Yes	None
5	Lock up	No	Flupropanate
6	Lock up	No	None
7	Strategic	Yes	Glyphosate
8	Strategic	Yes	None
9	Strategic	No	Flupropanate
10	Strategic	No	None

Table 5.2 Treatments applied at the Toolleen regional best practice site.

Treatment	Grazing regime	Resow pasture	Herbicide
1	Set stock	No	None
2	Set stock	No	Flupropanate
3	Lock up	Yes	Glyphosate
4	Lock up	No	Flupropanate
5	Lock up	No	None
6	Strategic	Yes	Glyphosate
7	Strategic	No	Flupropanate
8	Strategic	No	None

Table 5.3 Treatments applied at the Glen Innes regional best practice site.

Treatment	Grazing	Herbicide	Herbicide mode	Cropping	Resow pasture
1	Set Stock	None	None	No	No
2	Set Stock	Glyphosate	Selective rate	No	No
3	Set Stock	Glyphosate	Non Selective rate	No	Yes
4	Set Stock	Glyphosate	Non Selective rate	Yes	Yes
5	Strategic	Glyphosate	Selective rate	No	No
6	Strategic	Glyphosate	Non Selective rate	No	Yes
7	Strategic	Glyphosate	Non Selective rate	Yes	Yes
8	Set Stock	Glyphosate	Spraytop	No	No
9	Strategic	Glyphosate	Spraytop	No	No
10	Strategic	None	None	No	No
11	Set Stock	Flupropanate	Label rate	No	No
12	Strategic	Flupropanate	Label rate	No	No

Figure 5.12 Resowing pasture using combine into unsprayed and sprayed plots - Greenvale 2004.

5.3.8 Glyphosate application

Plots that required glyphosate application prior to resowing at Glen Innes were sprayed on the 18th March 2004 with glyphosate at a rate of 1.125 kg a.i./ha. Plots using selective glyphosate rates were sprayed on the 18th March 2004 with glyphosate at a rate of 540 g a.i./ha. These plots were resprayed with glyphosate on the 14th April 2004 due to heavy storm rain within two hours of the initial spray application on the 18th March 2004. Plots that required glyphosate application prior to sowing at Greenvale were sprayed on the 4th of May 2004 with glyphosate at a rate of 1.08 kg a.i./ha. Plots that required glyphosate application prior to sowing at Toolleen were sprayed on the 4th June 2004 with glyphosate (450g a.i./l) at rate of 2.5l/ha. Plots that required glyphosate application prior to sowing at Goulburn were sprayed on the 18th February 2005 with glyphosate (360g a.i./l) at rate of 2l/ha.

Spraytop plots at Glen Innes were sprayed with glyphosate at 180g a.i./ha on the 18th November 2003 and followed up again on the 11th November 2005.

5.3.9 Setup and sampling

The pasture composition was recorded in each plot, at each site, on a seasonal basis (Table 5.4). Pasture composition was measured at a fixed location within each plot using a 100 point 1 x 1 m quadrat (10 cm x 10 cm divisions) recording basal observations. The basal measurements recorded were - CNG, perennial desirable grasses (e.g. *Festuca arundinacea, Phalaris aquatica, Lolium perenne, Dactylis glomerata*), broadleaf weeds (e.g. *Arctotheca calendula Cirsium vulgare, oxalis spp.*), other annual grasses (e.g. *Lolium rigidum, Romulea rosea, Hordeum leporinum*), legumes (*Trifolium spp.*), vegetative litter and bare soil.

Table 5.4 Dates of seasonal data collection at regional best practice sites.

Season	Greenvale	Toolleen	Goulburn	Glen Innes
Summer 2003/04	*	*	27-Feb	*
Autumn 2003	1-May	13-May	28-May	*
Winter 2003	20-Jul	7-Aug	31-Jul	*
Spring 2003	9-Oct	30-Sep	7-Nov	17-Jul
Summer 2003	5-Dec	8-Dec	*	19-Nov
Autumn 2004	22-Mar	10-Mar	2-Apr	10-Mar
			11-May	13-May
Winter 2004	9-Jun	8-Jun	16-Sep	1-Sep
Spring 2004	2-Sep	3-Sep	13-Dec	*
Summer 2004/2005	22-Dec	2-Dec	31-Jan	31-Jan
Autumn 2005	*	29-Mar	26-May	16-Mar
Winter 2005	20-Jul	21-Jul	15-Aug	6-Jul
Spring 2005	20-Sep	21-Sep	28-Nov	30-Aug
Summer 2005/2006	23-Dec	6-Dec	*	5-Jan

Reproductive stems of all pasture species were harvested at ground level in each plot prior to seedfall using hand shears at Glen Innes on the 23rd December 2005 (500 mm x 300 mm quadrat), at Goulburn on the 13th December 2005 (500 x 500 mm quadrat), at Toolleen on the 6th December 2005 (300 mm x 330 mm quadrat) and at Greenvale on the 8th December 2005 (300 mm x 330 mm quadrat). Stems were dried, sorted and CNG panicle seeds removed and weighed. A calibration equation was also calculated from the seed weights (Table 5.6). Seed viability was tested by squeezing the seed body with tweezers to see, and feel, whether the seed was filled or unfilled.

Table 5.5 Soil test summary for each trial site.

Measurement	Unit	Greenvale	Toolleen	Goulburn	Glen Innes
pH (1:5 water)		5.57	6.30	5.90	5.8
Phosphorus (Olsen P)	mg/kg	10.33	5.00		
(Colwell)	mg/kg			21.00	
(Bray)	mg/kg	8.00	3.90	13.00	12
Potassium (Skene)	mg/kg	110.00	350.00		
(Colwell)	mg/kg			307.00	
(Amm.Ac.)	meq/100g			0.60	0.4
Sulfur (CPC by ICP)	mg/kg	8.00	7.00		
(KCL40)	mg/kg			18.00	5
Sodium (NH_4OAc exchange)	meq/100g	0.80	0.32		
(Amm Ac.)	meq/100g			0.20	<0.1
Calcium	% of cations	46.00	49.00		65
(Amm.Ac.)	meq/100g			8.18	

Table 5.6 Panicle seed calibration equations for each trial site (2005 season).

y = number of panicle seeds, x = weight of panicle seeds (g)(including awns)

Site	Calibration equation	R^2 value
Greenvale	y = 102.22x + 1.0851	0.988
Toolleen	y = 91.571x - 1.8978	0.9957
Goulburn	y = 91.665x + 0.9646	0.9989
Glen Innes	y = 157.5x - 2.3587	0.9921

Table 5.7 Pasture seed mix, sowing rate and fertiliser application rate for each regional best practice site (kg/ha).

	Greenvale		Toolleen		Goulburn		Glen Innes		
Date	Pasture 19th May 2003	Pasture 6th April 2004	Pasture 26th June 2003	Pasture 17th June 2004	Pasture 1st May 2003	Pasture 5th July 2005	Pasture 8th July 2005	Crop/resow 20th July 2005	Crop/resow 18th October 2005
Pasture sowing fertiliser (kg/ha)									
Nitrogen	18.0	18	18.0	18	15	15	17.9	17.9	17.9
Phosphorus	28.8	20	28.8	20	21	21	15.0	15.0	15.0
Potassium	16.4	0	16.4	0	0	0	0	0	0
Sulfur	12.6	1.6	12.6	1.6	7	7	13.1	13.1	13.1
Pasture seeds (kg/ha)									
Cocksfoot[A] Kara	3.0	5	3.0	5	2.5	0.8			
Cocksfoot[A] Porto					2.5	0.8	2	2	2
Phalaris[B] Australian					5.0	1.6			
Phalaris[B] Holdfast		3		3	5.0	1.6	3	3	3
Phalaris[B] Sirosa		3		3					
Ryegrass[C] Lincoln					2.5	0.8			
Ryegrass[C] Boomer						0.8			
Ryegrass[C] Kingston AS					2.5		2	2	
Ryegrass[C] Victorian		2		2					
Subterranean clover[D] Goulburn	6.0	2.5	6.0	2.5	2.5	0.8			
Subterranean clover[D] Seaton Park					2.5	0.8			
Subterranean clover[D] Trikkala		2.5		2.5					
White clover[E]							2	2	2
Red clover[F]									
Tall fescue[G] Jessup	9.0		9.0						
Tall fescue[G] Flecha	9.0		9.0						
Tall fescue[G] Demeter							5	5	5
Total pasture seed sown	27.0	18	27.0	18	25.0	8	14	14	14

[A] Cocksfoot (*Dactylis glomerata*) [B] Phalaris (*Phalaris aquatica*) [C] Ryegrass (*Lolium perenne*) [D] Subterranean clover (*Trifolium subterraneum*) [E] White clover (*Trifolium repens*)

[F] Red clover (*Trifolium pratense*) [G] Tall fescue (*Festuca arundinacea*)

Note: Sub clover seed was lime coated and inoculated. Seed rate is expressed as equivalent sowing rate of bare seed.

5.3.10 Statistical analysis - Greenvale and Goulburn basal cover

At each sampling occasion, each pasture basal cover component (measured as a percentage of total ground) was analysed using a randomised block analysis of variance after the measurement for each plot had been angularly transformed. Preliminary examination of the data indicated that most of the treatment differences could be categorised as differences between 5 treatment groupings. These groupings were:

(i) set stocked grazing with flupropanate (set flu);
(ii) set stocked grazing with no herbicide and no resowing (set);
(iii) strategic grazing or lockup with flupropanate (other flu);
(iv) strategic grazing or lockup with glyphosate and resowing (other gly); and
(v) strategic grazing or lockup without herbicide and with or without sowing (other no herb).

Thus, the treatment effects in the analyses of variance were divided into the 5 groupings, and then into any effect of treatment within the 5 groupings.

Graphs of the angularly transformed means of the 5 treatment groupings are presented for each of the basal cover components. As there were different numbers of treatments contributing to each of the groupings, the precision of different treatment grouping comparisons differ. Thus, at each sampling occasion, the maximum standard error of difference between groupings is presented pictorially on the graphs. At each sampling occasion, P-values are presented in the plots for differences between any of the five treatment groupings, and also between any treatment combination within these groupings. On sampling occasions when most plots in most treatments have zero values for a particular basal cover component, and thus standard errors and P-values were unreliable, the calculated standard errors and P-values are not presented on the profile plot.

5.3.11 Statistical analysis - Toolleen basal cover

Analysis for Toolleen basal cover was the same as for Greenvale and Goulburn other than that preliminary examination of the data indicated that most of the treatment differences could be categorised as differences between 5 treatment groupings. These groupings are

(i) set stocked grazing with flupropanate (set flu),

(ii) set stocked grazing with no herbicide and no resowing (set),

(iii) strategic grazing or lockup with flupropanate (other flu),

(iv) strategic or lockup with glyphosate and resowing (other gly), and

(v) strategic grazing or lockup without herbicide and without sowing (other no herb).

5.3.12 Statistical analysis - Glen Innes basal cover

Different treatment groupings have been used for statistical analysis of the Glen Innes site because the treatment structure was different at this site to the other sites.

At each sampling occasion, each pasture basal cover component (measured as a percentage of total ground) was analysed using a 5 management (control, flupropanate, glyphosate, pasture resowing, spraytopping) by 2 grazing methods (set stock grazing, strategic grazing) factorial, randomised block analysis of variance after the measurement for each plot had been angularly transformed. Cropping management was excluded from all analyses because very little CNG or perennial grass was observed within this treatment.

Graphs of the angularly transformed means of the 5 managements (excluding cropping), and profile plots of the angularly transformed means of the 2 grazing methods, are presented for each of the basal cover components. At each sampling occasion, within the graphs the standard error of difference between managements or between grazing method, as appropriate, is presented pictorially on the profile plots. At each sampling occasion, P-values are presented in the management profile plots for differences between any of the five managements, and P-values for grazing method and the interaction of management and grazing method are presented in the grazing method graphs. On sampling occasions when most plots in most treatments have zero values for a particular basal cover component, and thus standard errors and P-values are unreliable, the calculated standard errors and P-values are not presented on the graph.

5.3.13 Statistical analysis - Greenvale and Toolleen 2005 Panicle Seed Harvest

For each of Greenvale and Toolleen, panicle seed weight (g/m^2), after log(y+1) transformation, and panicle seed viability (%), after angular transformation, were analysed using a randomised block analysis of variance. Preliminary examination of the data indicated that most of the treatment differences could be categorised as differences between 6 treatment groupings. These groupings were:

(i) set stocked grazing with flupropanate;
(ii) strategic grazing with flupropanate;
(iii) lockup with flupropanate;
(iv) set stock grazing with glyphosate or no herbicide;
(v) strategic grazing with glyphosate or no herbicide; and
(vi) lockup with glyphosate or no herbicide.

Thus, the treatment effects in the analyses of variance were divided into these 6 groupings, and then into any effect of treatment within these 6 groupings.

5.3.14 Statistical analysis - Goulburn 2005 panicle seed harvest

Seed weight (g/m^2), after logarithmic transformation, and panicle seed viability (%), after angular transformation, were analysed using a randomised block analysis of variance. Preliminary examination of the data indicated that most of the treatment differences could be categorised as differences between 8 treatment groupings. These groupings were the combinations of grazing management (set stocked grazing, strategic grazing, lockup) and herbicide (flupropanate, glyphosate, no herbicide), excluding set stocking with glyphosate which was not represented in the treatments. Thus, the treatment effects in the analyses of variance were divided into these 8 groupings, and then into any effect of treatment within these 8 groupings.

5.3.15 Statistical Analysis - Glen Innes 2005 Panicle Seed Harvest

Seed weight (g/m^2), after log(y+1) transformation, and panicle seed viability (%), after angular transformation, were analysed using a randomised block analysis of variance. Preliminary examination of the data indicated that most of the treatment differences could be categorised as differences between 8 treatment groupings. These groupings were the combinations of grazing management (set stocked grazing, strategic grazing) and herbicide (flupropanate, glyphosate, spraytop, no herbicide). The no herbicide management combines the pasture management with the control management. Thus, the treatment effects in the analyses of variance were divided into these 8 groupings, and then into any effect of treatment within these 8 groupings.

5.4 Results

5.4.1 Greenvale

Chilean needle grass basal cover

Basal CNG cover at the start of the trial was about 10%. But in 4 of the 5 treatment groupings this increased to 15-40% by the end of the trial (Figure 5.13). During the trial, flupropanate significantly (P = 0.015) reduced the CNG basal cover in 'other flupropanate' and 'set stock flupropanate' plots when compared to other treatments. The effect of flupropanate was short lived for 'set stock flupropanate' plots where as 'other flupropanate' plots had a reduced CNG basal cover until the conclusion of the trial.

Application of glyphosate and resowing ('other glyphosate') significantly (P = 0.001) reduced the CNG basal cover from summer 2004/05 to winter 2005 when compared with 'set stock no spray' plots. 'Set stock no spray' plots had a consistently high CNG basal cover.

Desirable perennial grass basal cover

All treatments during 2003 had similar levels of perennial grass basal cover that ranged from as low as 1% up to 20% during seasonal growth patterns (Figure 5.14). The effect of set stock grazing, irrespective of flupropanate application ('set' and 'set flu'), reduced the amount of desirable perennial grasses to below 2% by the end of the trial. However, most other treatments had above 10% desirable perennial grass basal cover with 'Other flu' plots generally having 30% desirable perennial grass basal cover. This amount was significantly more desirable perennial grass than both the unsprayed plots ('other no herb') and the set stock flupropanate plots ('set flu') from winter 2005 onwards ($P = 0.005$, $P= 0.005$, $P < 0.001$).

Annual grass basal cover

Annual grass basal cover rose in winter and spring and fell during summer and autumn in all treatments with the lifecycles of these annual grasses. While there were no consistent trends from year to year, unsprayed set stock plots had significantly more annual grass basal cover during winter 2004 than all other treatments ($P < 0.001$)(Figure 5.15). 'Other graze' plots that were unsprayed also had more annual grass cover than 'other graze' plots that were sprayed with glyphosate and resown. 'Set stock flupropanate' plots had significantly more annual grasses than 'other graze' unsprayed and glyphosate sprayed plots during spring 2005 ($P = 0.036$).

Broadleaf weed basal cover

Broadleaf weed basal cover remained below 5% for most treatments over the seasons (Figure 5.16), but by the end of the trial 'set flu' plots had significantly more broadleaf weeds (20% cover) than any other treatment ($P = 0.0073$ except 'other graze flupropanate', $P < 0.001$). Within the 'other no herb' and grazed treatments, strategically grazed plots often had more broadleaf weeds than the corresponding lockup grazed treatments ($P = 0.05$, $P = 0.043$, $P = 0.010$).

Vegetative litter basal cover

Vegetative litter basal cover fluctuated throughout the seasons dependant on rainfall and seasonal growth (Figure 5.17). Resown plots ('other gly') had higher amounts of vegetative litter in the year following sowing (40%) when compared to all other treatments (10%) although this pattern did not continue.

By the summer of 2004 'set flu' plots had significantly less vegetative litter basal cover than most other treatments ('other graze flupropanate' and 'set stock unsprayed,' $P = 0.042$). This difference continued to grow and by the end of the trial 'set flu' plots had significantly less vegetative litter basal cover than all other treatments ($P = 0.015$, $P < 0.001$).

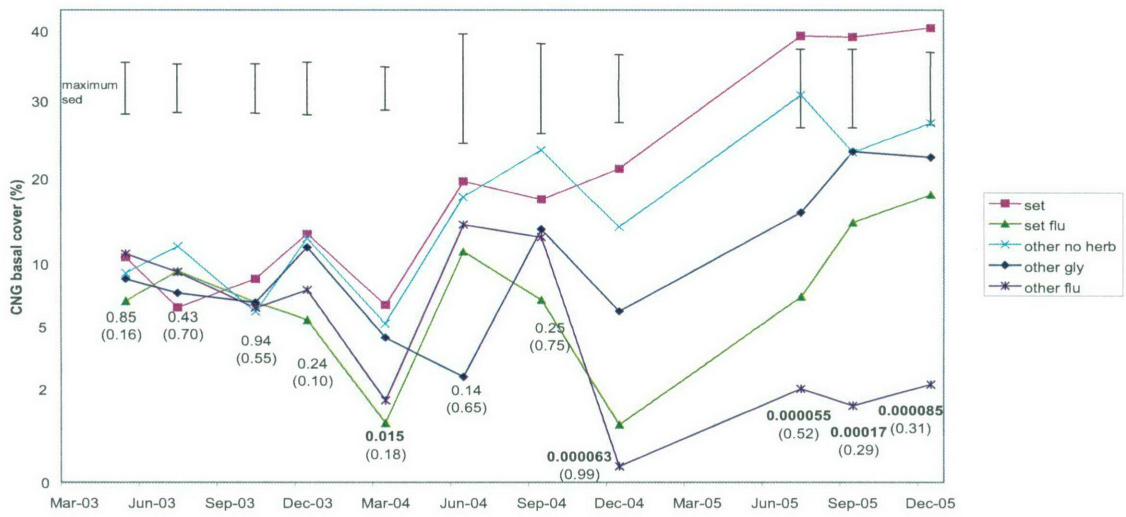

Figure 5.13 Effect of grazing management (Set stocked or other; combined lockup and strategic graze) and herbicide (none, glyphosate and flupropanate) on CNG basal cover in pasture at the Greenvale best practice management site. P values presented for between treatment groupings and within treatment groupings (in brackets).

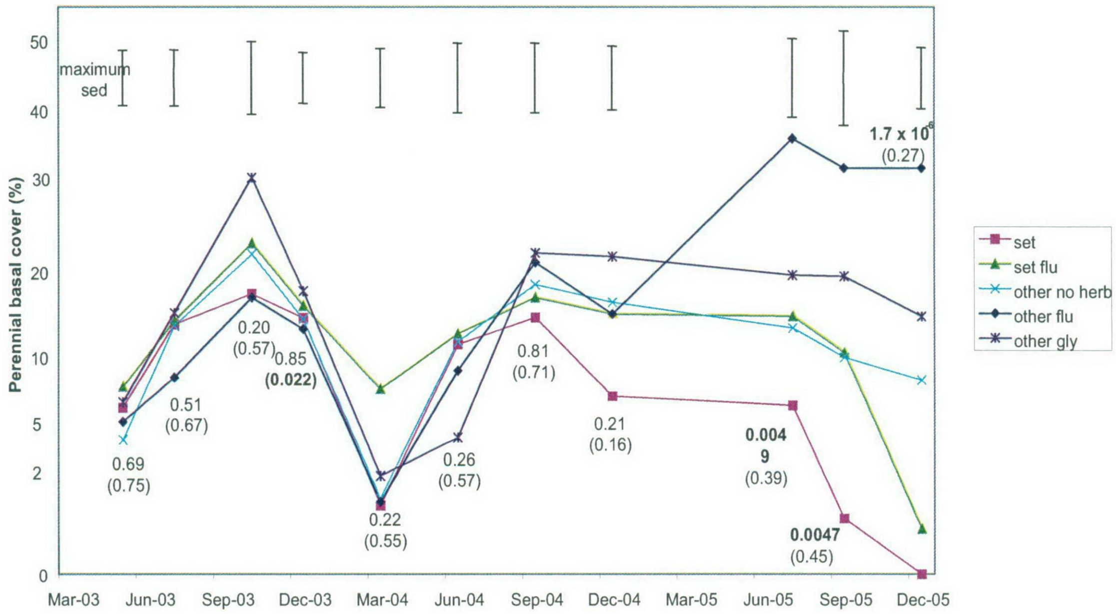

Figure 5.14 Effect of grazing management (Set stocked or other; combined lockup and strategic graze) and herbicide (none, glyphosate and flupropanate) on perennial grass basal cover in pasture at the Greenvale best practice management site. P values presented for between treatment groupings and within treatment groupings (in brackets).

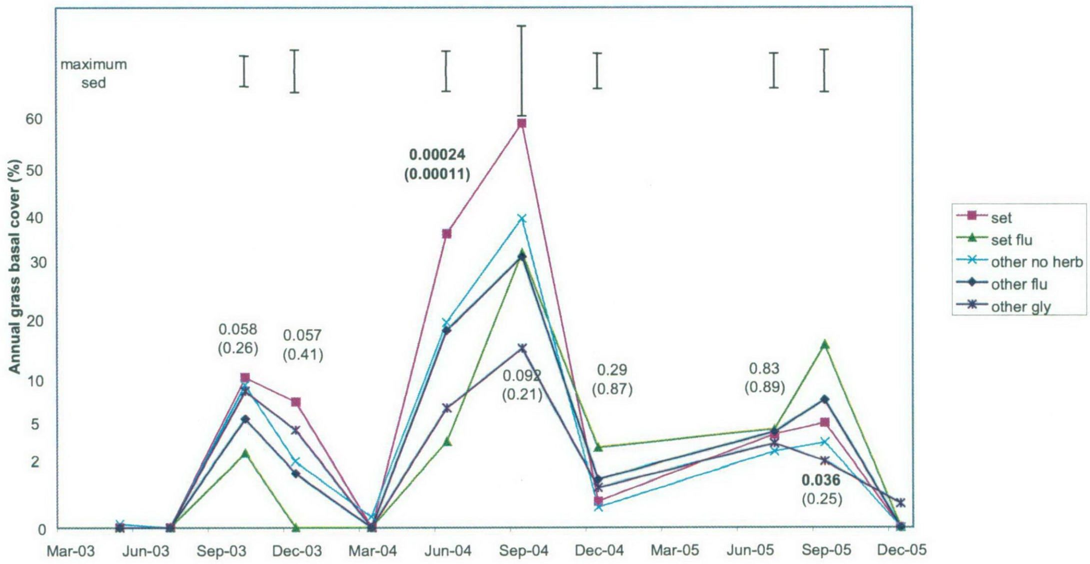

Figure 5.15 Effect of grazing management (Set stocked or other; combined lockup and strategic graze) and herbicide (none, glyphosate and flupropanate) on annual grass basal cover in pasture at the Greenvale best practice management site. P values presented for between treatment groupings and within treatment groupings (in brackets).

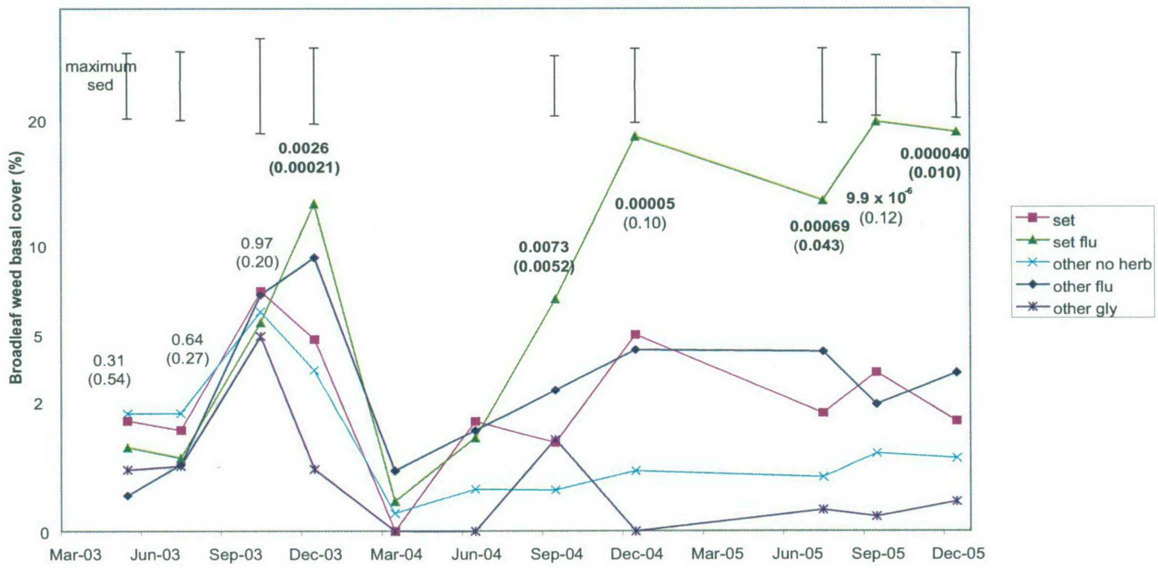

Figure 5.16 Effect of grazing management (Set stocked or other; combined lockup and strategic graze) and herbicide (none, glyphosate and flupropanate) on broadleaf weed basal cover in pasture at the Greenvale best practice management site. P values presented for between treatment groupings and within treatment groupings (in brackets).

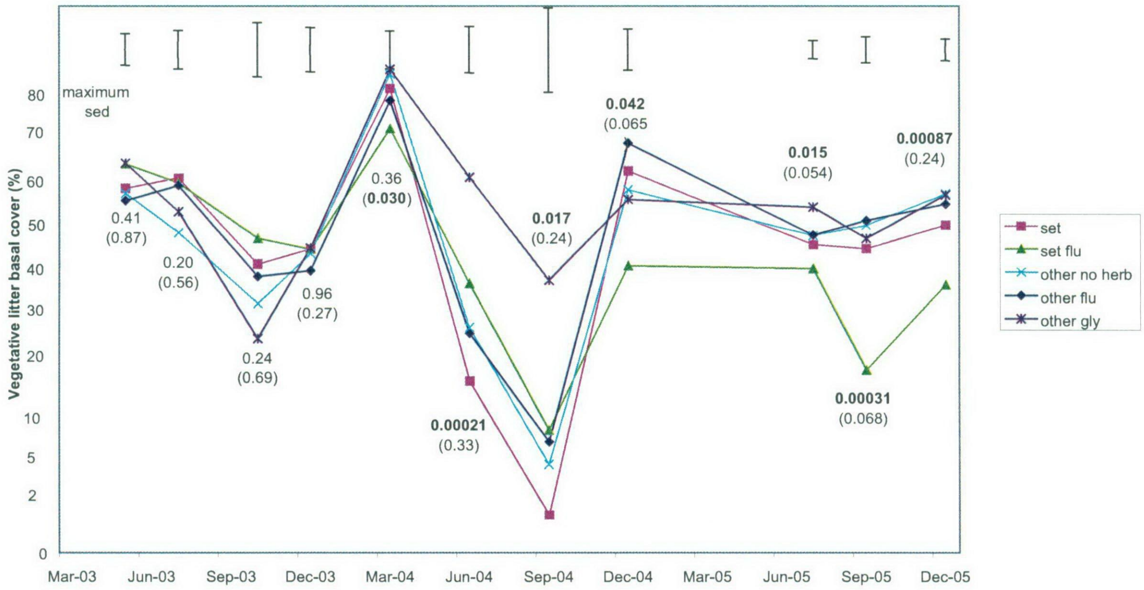

Figure 5.17 Effect of grazing management (Set stocked or other; combined lockup and strategic graze) and herbicide (none, glyphosate and flupropanate) on vegetative litter basal cover in pasture at the Greenvale best practice management site. P values presented for between treatment groupings and within treatment groupings (in brackets).

Soil basal cover

From autumn 2004 onwards, 'set stock flupropanate' plots had higher levels of bare soil than any other treatment and this was significant from winter 2005 onwards (Figure 5.18).

Legume basal cover

Legume basal cover remained low (generally less than 3%) throughout the trial and was generally not affected by grazing management or herbicide addition (Figure 5.19). Any significant treatment effects were isolated and discrete.

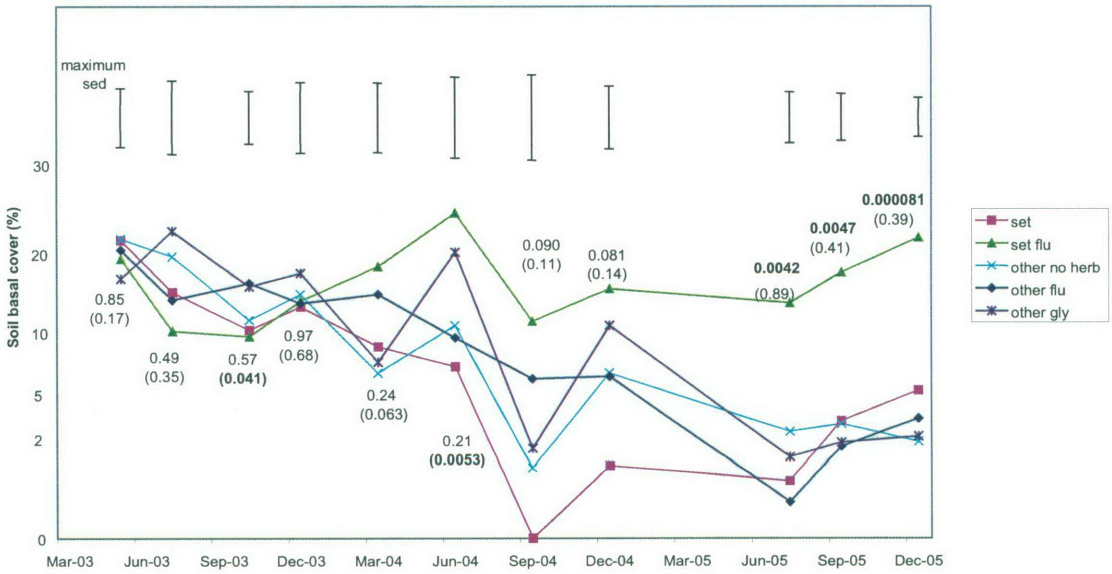

Figure 5.18 Effect of grazing management (Set stocked or other; combined lockup and strategic graze) and herbicide (none, glyphosate and flupropanate) on bare soil in pasture at the Greenvale best practice management site. P values presented for between treatment groupings and within treatment groupings (in brackets).

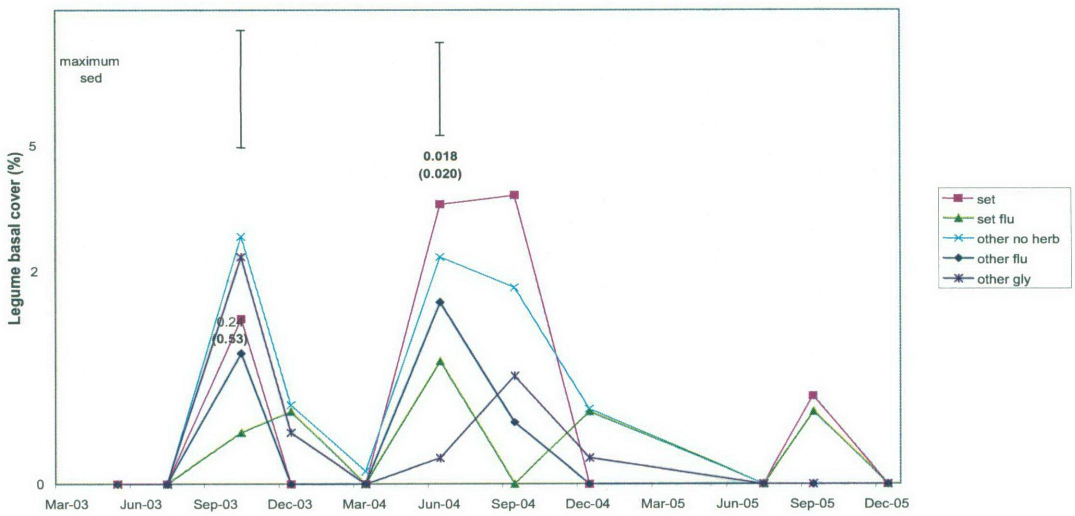

Figure 5.19 Effect of grazing management (Set stocked or other; combined lockup and strategic graze) and herbicide (none, glyphosate and flupropanate) on legume basal cover in pasture at the Greenvale best practice management site. P values presented for between treatment groupings and within treatment groupings (in brackets).

Panicle seed harvest and viability

Plots that were sprayed with flupropanate had significantly less standing CNG panicle seed than unsprayed plots during spring 2005 ($P < 0.001$)(0). Strategically grazed plots (flupropanate sprayed or non flupropanate sprayed) had significantly less standing CNG panicle seed than their respective lockup or set stock plots ($P < 0.001$). CNG seed harvested from set stock plots tended to have a lower viability than seed harvested from strategically grazed or lockup plots ($P = 0.056$). The treatments had no consistent affect on CNG seed viability.

Table 5.8 Effect of treatments on panicle seed production and viability at the Greenvale best practice management site 2005.

Measurement	Flupropanate			No flupropanate (including glyphosate/resow and no spray)			s.e.d.			P Value	
	Set Stock ^{A}	Strategic^{A}	Lockup^{A}	Set Stock^{B}	Strategic^{B}	Lockup^{B}	A vs A	B vs B	A vs B	Between shown treatment combinations	Within shown treatment combinations
Panicle seed wt (g/m^2)											
Log (y+1) transformed	0.26	0.01	0.10	1.31	0.71	1.24	0.265	0.153	0.217	**0.000022**	0.760
Backtransformed	0.8	0.0	0.3	19.6	4.1	16.2	-	-	-		
Panicle seed viability (%)											
Angular transformed	61	83	91	64	75	78	9.5	5.5	7.7	0.056	0.136
Backtransformed	76	98	100	81	93	96	-	-	-		